Augmented Virtuality for Head-Mounted Displays

Improving User Experience by Incorporating the Real into the Virtual

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1. INTRODUCTION

Consumer level Virtual Reality (VR) experiences are about to arrive in the form of Head-Mounted Displays (HMDs) such as the Oculus Rift[7] and HTC Vive[5]. VR has seen a massive resurgence in recent years, and by 2020, the industry is expected to be worth approximately $30 billion. With about half of the market being accounted for by VR games[4], computer gamers are the key demographic for consumer HMDs[15]. Although projections like this may seem overly optimistic, technology has come a long way since the 90s VR bubble burst. The problems previously faced by consumer grade VR experiences (such as low resolution, small field of view, uncomfortable weight, motion-sickness inducing latency, and poor graphical quality[13]) have been largely addressed[15].

Given the expected ubiquity of HMDs, it is important to consider how and where they will be used, and who will be using them. Since personal entertainment (video games in particular) will be a primary function of consumer level VR, it is of particular importance to consider the context of home usage[15]. Despite the fact that video games are meant to place players in a virtual world, to the potential (if not deliberate) exclusion of the real world, a considerable number of real world interactions still take place. Examples of these interactions include the use of peripherals such as a keyboard, or taking a drink. The complete visual exclusion of the real world by HMDs, while affording greater immersion, makes interactions as trivial and natural as these far more difficult.

For VR gaming to be as fully embraced as traditional gaming (using conventional computer monitors), real world interactions commonly performed by gamers should be facilitated. Augmented Virtuality may offer a solution. Augmented Virtuality (AV), as opposed to Augmented Reality (AR), is the addition of elements of the real into the virtual[18]. A forward facing camera affixed to the front of an HMD could give the wearer a view of reality, effectively letting the user "see through" the device. Allowing users to see the real world through their HMD would facilitate real world interaction without forcing the user to completely disengage from what they are doing by removing it.

The aim of this research is to modify an existing approach to AV and evaluate its effectiveness in terms of facilitating real word interaction, and preserving the sense of immersion experienced by the user.

2. RELATED WORK

VR attempts to heighten the way that people experience virtual environments. Technologically, the largest difference between VR and a conventional monitor setup, is the display. Incarnations of VR such as CAVE, and "wedge"[13], for example, project multiple views of the virtual environment onto the walls of a room in which the user stands, whereas HMDs use two small screens, one in front of each eye, to create the illusion of depth[20]. Many implementations of VR also make use of positional tracking, such that the movements of the user are directly translated into movements in the virtual environment. Room scale VR utilizes this positional tracking to a larger extent than HMDs (with the possible exception of the HTC Vive), allowing users to walk around freely in the real/virtual room. In contrast, the Oculus Rift tracks only the user's head, and is intended for more of a "sitting down" experience with more conventional controls. The more affordable and practical nature of HMDs, as opposed to room scale VR, is the reason they are the main focus of this research. Despite the various differences between VR implementations, they share a common goal: a heightened sense of Presence[24].

Presence[22] can be loosely defined as the user's sense of "being" in a virtual environment. For an individual experiencing Presence in a virtual environment, equipment (displays and controllers) and physical surroundings fade away, leaving the impression that the virtual world that they are in is more real than their actual reality at the point. In short, Presence is is the feeling of being in one place, while physically being in another[28]. VR strives to create this experience to a far greater extent than is possible using normal computer monitors. Presence is very important for games, and the effectiveness of virtual environments has often been linked to the amount of Presence experienced by users [28]. As noted by Weibel and Wissmath[27], the pleasure of being immersed in a virtual world is a primary reason to play games, and Presence is a core component of immersion.

Of the various ways in which VR can be implemented, the HMD is perhaps the most practical for consumers. HMDs are small, light, and relatively inexpensive, while offering high fidelity visuals and audio. However, there is one major problem with the way they create a sense of Presence: they cut the wearer off visually from their surroundings. Not only are users cut off from the tools and peripherals they may need for whatever activity they are engaged in (such as input devices)[8], but also from all other real-world objects they may wish to interact with. The argument could be made that the entire point of video games, immersive or not, is to cut the user off from the real world. Why then, should it matter, if users are now visually cut off from that world as well? The answer is manifold.

2.1 Problems with HMDs

Certain tasks, such as text entry, are very difficult to accomplish without the sense of sight[15]. Although a subset of keyboard commands, or the mapping of a controller, can be memorized and used for gameplay[8], these are inadequate for tasks that require a greater bandwidth of input. In fact, current HMD users rate the inability to provide input into VR as as greater impediment to widespread adoption than the hitherto rather common HMD induced nausea[15].

Text entry, especially in online multiplayer games, is remarkably prevalent. Almost every online multiplayer game has a text chat box in a corner of the heads-up display[19]. An analysis of communication in the game *World of Warcraft*[1] showed that nearly half a million text messages were sent in the 11775 recorded sessions, an average of about 40 text messages per session (where the average session lasted 57 minutes)[25]. This amounts to an average of more than one text message being sent every two minutes per player. In fact, the dominant form of communication in games of several genres is text [12]. The effectiveness of voice-based communication for cooperative endeavours and task coordination[14] lends itself to use in those situations, but text-based chat is used for socio-emotional communication to a large extent[19, 12]. Text-based communication is seemingly entrenched in the social and emotional aspects of multiplayer gaming. This is perhaps no more evident than in the recent case where text-based communication was not included in the popular *Metal Gear Solid V:MGS Online*[2], leading to outrage amongst the franchise's fan base. To quote one Mr. GGscrub, "Wtf like, it was an essential part of the charm of MGO2! How the hell is it missing?" [3]. The sentiment is echoed by CanOpener74 ("really not a good change, this... sadness... pervades.") and many others [3, 6]. Text-based chat in games is not going away any time soon.

The objects that people wish to interact with while they are playing games are not limited to peripherals used for playing the games. Studies have shown that 67% of the time spent playing computer games is also spent doing something else[10]. 40% of the actions constituting that "something else" are real-world interactions not directly linked to the game being played, such as eating or drinking, reading, homework, and using a cellphone[10]. Currently, HMD users rate their ability to interact with objects as extremely ineffective[15].

Text-based communication (and input in general), as well as real-world interactions, are common enough tasks among computer gamers to be given some attention in terms of how we can help users execute them.

2.2 Living with an HMD

Although the first consumer level VR hardware has only recently begun shipping, earlier development versions of the hardware (such as the Oculus Rift DK1 and DK2) have been in use by early adopters for some time. This has allowed for the usage of these devices to be studied, and to find out how people are dealing with the visual cutoff created by HMDs. The "solutions" (if indeed we can call them that) that users have come up with, are not particularly good. Chief among them are "peeping", "groping", and isolation. Peeping involves temporarily lifting the device off one's eyes in order to gain awareness of, or interact with, the real world. Groping is an attempt to interact with the real world without removing the HMD. Isolation, a very common behaviour among early HMD adopters(approximately 80% of whom report doing this[15]), involves play sessions taking place with no other people or real-world objects around, a total exclusion of reality. HMD users agree that having to resort to peeping is frustrating [15] (this is unsurprising, as it is akin to having to turn off one's monitor every time one wanted to have a sip of tea). Furthermore, peeping defeats the primary purpose of the HMD, as lifting it off clearly constitutes a significant break in Presence. Isolation, deliberately forgoing all the activities one may usually partake in while playing a game, is unlikely to be accepted by the majority of users, especially considering how prevalent real-world interactions are while playing games. It is important to note here that, apart from peeping, the visual cutoff created by wearing an HMD does not necessarily interfere with the usability of the HMD itself, but rather with the usability of peripherals and other objects. If VR gaming is to be as ubiquitous as traditional gaming is today, the usability issues created by HMDs need to be better addressed.

2.3 Mixed Reality as a Potential Solution

Mixed Reality displays are a subset of VR technologies that merge the real world, and virtual worlds[17]. All mixed reality displays can be thought of as occupying a point somewhere along a "virtuality continuum" as illustrated in Figure 1. The widely known AR is closer to the Reality side of the spectrum, where the display of an entirely real environment has virtual artefacts added to it (predominantly real with few virtual elements). In AV, on the other hand, certain real objects are made visible in an otherwise entirely virtual environment (predominantly virtual with few real elements). One way in which AV can be implemented is by attaching a digital video camera (such as a webcam) to the front of an HMD to allow the wearer to "see through" the device[17]. By doing so, varying degrees of the real world, as seen by the camera, can be relayed to the HMD and superimposed over the display of the virtual world.

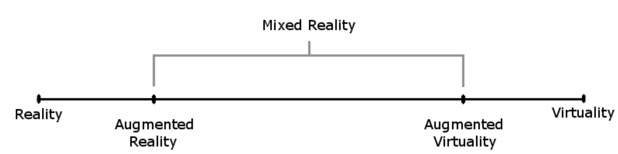


Figure 1: The Virtuality Continuum

A recent study assessed several AV techniques[15]. A series of experiments was conducted with the aim of assessing user performance and preference with respect to typing and real-world interaction in several AV conditions. The scores achieved were compared to a pure virtuality baseline (wearing an HMD and not ever taking it off), and a "peeping" baseline (lifting the HMD off the eyes when required). AV was implemented, in all cases, by passing various amounts of video from a standard webcam attached to the front of the HMD to the display when required. The AV conditions that were tested included full blending, partial blending, and minimal blending. In the full blending condition, the display of the HMD changes between showing a full view of the virtual world, and a full view of the real world. In partial blending, rather than the full view of reality being displayed, only the user's hands, peripherals, and objects to interact with were inserted into the view of the virtual world. In minimal blending, only a small area of the real world around the users hands was inserted into the virtual world. The methods differ in how much of the real world is shown, with full blending showing the most, minimal blending showing the least, and partial blending falling between the two. These differences can be seen in Figure [TODO FIGURE]. It was found that both minimal and partial blending performed better in terms of preserving the user's sense of Presence than when users "peeped". Furthermore, users far preferred partial and minimal blending to the baseline conditions in terms of how easy it was to interact with real-world objects. Finally, partial blending was found to increase typing performance compared to the baseline conditions (typing performance for the minimal blending condition was not assessed).

The research conducted by McGill et al.[15] revealed several useful results: Input and real-world interaction can be facilitated using AV; Only a small amount of reality needs to be displayed for AV to be effective; AV does not have an overly negative impact on Presence. However, there are several issues with the study. The effect of minimal blending on typing performance, compared to virtuality and reality baselines, was not assessed, and despite the insistence that the context of home and office usage be taken into account, both the minimal and partial blending techniques that were implemented are dependent on chroma-keying. This requires a user's entire desk/cubicle to be "green-screened" in order for these implementations to work. This is patently impractical for the average consumer, the target market for HMDs, and the very people whose experience AV is aimed at improving.

A similar study investigated several AV techniques purely in terms of facilitating real-world interaction[9]. AV implementations very similar to minimal, partial, and full blending were assessed as well as inset AV. Inset AV, proposed as early as twenty years ago, involves using the video pass through technique to create a small inset of reality as an overlay which is superimposed onto the virtual scene[16]. A major benefit of the inset method is that it does not require the use of chroma-keying. Unfortunately, Budhiraja et al.[9] found that inset AV did not perform well compared to their versions of minimal and partial blending, with users reporting difficultly mainly with the size discrepancy between what was displayed in the inset and what the actual sizes of objects were in the real world. Their results with respect to minimal and partial blending conditions were very similar to those obtained by McGill et al.[15], showing good performance in terms of real-world interaction and strong user preference. The minimal blending AV system implemented by Budhiraja et al. relies on color segmentation as opposed to chroma-keying to selectively display aspects of the real world (such as a users hands). While perhaps more practical than chroma-keying, color segmentation can be sensitive to skin tone, lighting conditions, and background contrast [26], all of which would inevitably lead to issues for consumers. A major difference between these two studies is the design of the transitional interface, or under what conditions reality is shown to the user. Budhiraja et al.[9] allowed the user to dictate, with the press of a button, when the AV system would become active. McGill et al.[15] found that allowing the users to choose when to activate AV scored far lower in terms of Presence and preference than what they call "inferred blending", where the AV system automatically activates based on context (e.g. when the user stretches their hands out in front of them). Budhiraja et al. mention such an augmentation to their system as potential future work.

Minimal blending AV seems to have the most potential for assisting HMD users in the home context. Minimal blending has a lower impact on Presence compared to other AV implementations, and results indicate that it facilitates both input tasks and other real-world interactions well. Furthermore, minimal blending is not strictly dependent on impractical or unreliable techniques such as chroma-keying or colour segmentation. For these reasons, this research will explore minimal blending further, attempting to replicate the positive results of previous work [15, 9] with a new implementation that is more practical for consumers.

3. RESEARCH QUESTIONS

The aim of this research is to investigate a version of minimal blending AV. It will be assessed in terms of its impact on Presence, and how well it enables users to complete real world tasks.

This research is important for several reasons. The fact that users of HMDs cannot see while wearing the device presents several usability issues. This, coupled with the expected popularity of these devices, dictates that we attempt to address these issues while preserving their main function (heightened immersion). In so doing, one of the few remaining obstacles that may prevent widespread adoption of HMDs will hopefully be removed. Previous work regarding minimal blending has shown it to have great promise. However, these implementations have relied on a chroma-key approach, which is clearly not practical for end users. This research will attempt to ascertain whether minimal blending can be as effective without the need to green-screen one's entertainment area.

The primary research question that will be investigated is as follows: *Can minimal blending AV be successfully implemented without the use of chroma-keying?*

For the purposes of this research, the success of an AV technique is defined by its effect on typing performance, real-world interaction, and Presence. In order, therefore, to answer the primary research question, the following research questions and hypotheses will be investigated:

3.1 Typing Performance

Is typing performance better in AV than in virtuality?

H_{A0} There is no difference in typing performance between AV and a virtuality baseline.

H_{A1} Typing performance is better in AV than in a virtuality baseline.

H_{A2} Typing performance is worse in AV than in a virtuality baseline.

3.2 Real-World Interaction

Does AV facilitate real-world interactions?

H_{B0} It is as difficult to perform real-world interactions in AV as it is in a virtuality baseline.

H_{B1} It is easier to perform real-world interactions in AV than it is in a virtuality baseline.

H_{B2} It is more difficult to perform real-world interactions in AV than it is in a virtuality baseline.

3.3 Presence

Is Presence lower in AV than it is in virtuality?

H_{C0} There is no difference in Presence scores in AV and in a virtuality baseline.

H_{C1} Presence scores are higher in AV than they are in a virtuality baseline.

H_{C2} Presence scores are lower in AV than they are in a virtuality baseline

4. METHODOLOGY

4.1 System Design

4.1.1 Design Features

The core design feature of the proposed system is an AV implementation based on the work of McGill et.al.[15]. The proposed system, however, will rely on hand tracking methods that do not require the use of the chroma-key technique, but rather use the hand tracking system built into the Leap Motion controller. In order to measure typing performance, the second important feature will be a simulated chat box, which will prompt users for text input and measure their responses. Both of these systems will be incorporated into an immersive, VR compatible game, which will be chosen/created with the goal of creating a sense of Presence in the player[1].

4.1.2 Development Platform

The development platform will be the Windows version of Unity3D.

4.1.3 Implementation Strategy

There are three main components to the system: The game; The AV system; The chat window. Unity3D allows for a high degree of modularity, so all three components can be developed independently. Since the focus of this research is on AV and its effects, the AV and chat systems will be developed first. These two systems could potentially be incorporated into any open source Unity game thanks to Unity's modular nature. Once these two systems are functional, the game itself will become the major focus.

4.1.4 Expected Challenges

The first major challenge will be the creation of the AV system. This system needs to operate with low latency, and high fidelity, in order to yield the best results. Furthermore, the smooth operation of this system requires that three separate pieces of technology (none of which the researcher has experience with) be made to work seamlessly together. Namely, an Oculus Rift, a Leap Motion controller, and a webcam. The chat box will also present several challenges - mainly in the form of how to generate text which is realistic in terms of length and content, but still useful for the measurement of text entry.

[1]Ideally, an existing game would be used. Game creation is not necessarily the focus of this research, and brings with it many obstacles and resource requirements. However, probably due to the newness of VR technology, preliminary searches for open source Unity3D games compatible with the Oculus Rift have been unsuccessful. If no such game is found, a game will have to be developed. This eventuality is not insurmountable, as the researcher has experience developing games in Unity3D.

4.2 Experimental Design

The experiment conducted will be a single-blind, between-groups design. The participants will be randomly allocated to one of two groups, and will not know which group they are in, or what the nature of the other group is.

The two groups are as follows:

1. Control Condition (Virtuality)

2. Experimental Condition (Augmented Virtuality)

In both cases, participants will play a game while wearing an HMD. During the course of gameplay, they will be prompted to complete several real-world tasks. Participants in both conditions will not be allowed to remove the HMD in order to help complete the tasks. In the Control condition, all elements of the AV system will be disabled. The AV system will be fully active in the Experimental condition.

A third group is not necessary, as baseline typing speed and real-world interaction in reality will be captured for each participant, pre-experiment. A between-groups design was chosen to limit contamination by extraneous factors, learning effects and fatigue in particular. However, this choice of design will require a larger number of participants in order for any effects to be detected to a reasonable degree of significance (compared to a within-subjects design).

The independent variable (IV) in this case is group (defined by the absence or presence of the AV system). The dependent variables (DVs) are Presence, ease of real-world interaction, and typing performance.

4.3 Procedure

4.3.1 Participants

Pseudo-random convenience sampling will be used to recruit participants. It is highly likely that none of the participants that are recruited will ever have had experience with immersive VR. As such, participants with computer and computer gaming experience will be favored. Participants with little to no computer/gaming experience will likely be overwhelmed by the plethora of new and unfamiliar technology in the experiment, which may affect their performance and responses. Computer Science undergraduate and Honours students will be the easiest to access, and likely to meet the stipulated criterion.

4.3.2 Pre-Experiment

Before the experiment begins, participants will be given a handout describing the nature of the experiment and the technology used therein. Care will be taken not to allude to any of the measures being used, in order to prevent bias. The use of a handout, rather than verbal instructions, will ensure a consistent pre-experiment experience for all participants, and reduce the risk of experimenter bias. The handout will serve as informed consent, and participants will sign if they are willing to proceed.

After this briefing, the baseline typing and interaction speed of the participant will be captured.

Finally, participants will be allowed to test out the system in a simple tutorial. This will allow them to familiarize themselves with the HMD and controls before they begin the experiment.

4.3.3 Experiment

During the course of the experiment, participants will play a game while wearing an HMD. While they are playing, they will be prompted several times to enter prescribed text into a chat window, and interact with real-world objects.

The play session will take place in a controlled environment with no external distractions. This same environment will be used for every participant. Each experiment will be conducted using exactly the same hardware. The experimenter will remain in the venue, but will not interfere in any way unless the participant requires aid.

After a predetermined amount of time (thirty minutes), the experimenter will instruct the participant to stop playing the game.

4.3.4 Post-Experiment

After the experiment is complete, the participant will be required to fill out several questionnaires in order to quantify aspects of their experience. After this, the participant will be allowed to leave. Their forms will be filed, and the data gathered by the apparatus will be organized and backed up.

4.4 Measures

4.4.1 Presence

In order to measure Presence, participants will fill in the SUS Presence questionnaire [22, 21] immediately after the experiment.

4.4.2 Typing Performance

Typing performance measures will be built into the apparatus itself. Various aspects of typing performance will be measured, including words per minute, accuracy, and time to first key press. In order to calculate accuracy, a modified version of the Levenshtein String Distance Statistic, as described by Soukoreff and MacKenzie[23], will be implemented.

During gameplay, participants will "receive messages" via a simulated chat box. The messages will consist of English words randomly selected from the top one thousand most commonly used words[2]. They will be alerted with audio and visual cues when they receive a message, and will have been instructed beforehand to enter the message immediately upon receipt. They will then have to enter that same message as a reply. Participants will be prompted to enter text in this manner six times during their gameplay session. All input will be recorded for analysis. Total scores for the measures specified will consist of the averages across all message responses.

4.4.3 Real World Interaction

After filling in the Presence questionnaire, participants will fill in the NASA Task Load Index (NASA-TLX) questionnaire [11]. This questionnaire is designed to measure work load, and will allow information about the ease of performing interactions to be gleaned. Recordings captured during experiments will later be analysed so that the time taken to complete real-world interactions can be measured. This will serve as a measure of task performance.

Tasks will consist of taking a sip of water from a mug on the desk, checking the time on a cellphone lying on the desk, and opening a packet of crisps. Each interaction will only have to be performed once during the course of the experiment. User's will be prompted by the game to execute each of these actions during the course of the session.

5. PROJECT PLAN

5.1 Risks

Please consult Table 1.

5.2 Resources

5.2.1 Hardware

This project aims to investigate issues pertaining to VR. In particular, VR achieved through the use of an HMD. As such, a consumer grade HMD will be necessary for this research. Due to it's popularity, wide user base, large volume of support, and integration with major game development platforms, the Oculus Rift is the preferred choice. The Oculus Rift CV1 (first commercial release), has recently begun shipping (28 March 2016[7]).

In order to support the Oculus Rift, a sufficiently powerful graphics workstation is required. The minimum necessary specifications are as follows[7]:

- Video Card: NVIDIA GTX 970
- CPU: Intel i5-4590
- Memory: 8GB+ RAM
- Video Output: free HDMI 1.3 output
- USB Ports: 3x USB 3.0 ports plus 1x USB 2.0 port
- OS: Windows 10 64 bit

Finally, in order to implement the various AV techniques under investigation, a Leap Motion controller will be required. This device combines the functions of both a hand-tracker, and stereoscopic camera that can be used for video pass-through. It is small enough to be mounted to the front of an HMD[3].

5.2.2 Software

In order to create the experimental apparatus, one core piece of software is required: The Unity3D development platform. This platform has been chosen for several reasons; I have previous experience with this development platform, using an alternative platform would require extra time to learn how the system works; Unity3D is widely used, there are many tutorials, and support can easily be found due to

[2]The six messages will be pre-generated and the same ones given to every participant, to ensure a uniform experience.

[3]Preliminary testing has revealed two weaknesses with the Leap Motion controller: The cameras used do not provide video pass though of sufficiently high fidelity to read the lettering on a keyboard, hampering its ability to facilitate text entry; Because the cameras used are infra-red, all screens (including mobile phone screens) appear completely blank, rendering them unusable. For these reasons, it may be necessary to acquire a webcam for video pass through

Table 1: Risks, Impact, and Management Strategies

Risks and Effects	Impact	Likelihood	Monitoring	Mitigation	Management
Delays in obtaining key hardware. This could result in delaying the whole project, and/or reducing the quality of the final system.	Catastrophic	7	Order tracking.	Order as early as possible.	Borrow older equipment.
Difficulties in obtaining participants. Results less likely to be significant.	High	9	Monitoring of sign-up sheets.	Power analysis to ensure I know how many participants I will need.	Reach out to friends, family, and university connections. Participation could possibly be used as extra credit for Psych undergrads.
Development delays. Could delay final experimentation and put pressure on subsequent milestones.	Medium	5	Weekly checks to ensure development is on schedule.	Detailed breakdown of sub-tasks and sub-systems required for final system created before development begins.	Sleep less.
Hardware malfunction/failure. Equipment would have to be sent overseas for repair. Potentially enormous delay to development/ experimentation.	Catastrophic	1	Weekly hardware checks.	Strict adherence to pre-established care protocol.	Fall back to borrowed hardware.
Writing delays. Could delay final hand-in.	Low	4	Weekly supervisor meetings.	Weekly supervisor meetings.	Sleep less.

its large user base; The Unity3D development platform has built in support for both the Oculus Rift and Leap Motion controller; Finally, only the free version of Unity3D will be required.

5.2.3 *People*

A number of participants will be required to participate in initial pilot experiments. Thereafter, a larger number of participants will be required to participate in final experiments. The number of participants that take part in the final experiment should be sufficiently large in order for any potential effects to be detected with a significant degree of confidence. This number will be determined using power analysis.

Before either the pilot or final experiments are conducted, ethics clearance will have to be obtained.

5.3 Milestones

Table 2: Project Milestones

Date	Milestone
01/06/2016	Introduction and Background chapters done.
01/12/2016	Development complete.
31/12/2016	Pilot experiments conducted.
31/01/2017	Apparatus finalized.
28/02/2017	Data gathered (experiments complete)
01/04/2017	Results, Conclusion, Abstract complete.
01/06/2017	Final Draft hand-in.
01/07/2017	Final hand-in.

5.4 Timeline

Please see the proposed timeline (Appendix A), for a more detailed breakdown of the milestones above.

6. RESEARCH OUTCOMES

6.1 System

The system that will be created will be an immersive 3D game that will allow users to experience a sense of Presence. Furthermore, the game will implement an AV technique (Minimal Blending AV). In order to test typing performance while in the virtual environment, a chat simulator will also be built into the game which is capable of measuring all the necessary details of user input. If the chat box and AV systems are of a high enough quality, they could be turned into assets available for download on the Unity Asset Store.

The key feature of the system will be the AV system that will be built into it.

The main design challenge will be the implementation of the AV system, as three separate pieces of hardware will have to work in concert. Making the chat simulator fairly realistic while also still useful as a measurement instrument will also be challenging. Finally, adding enough polish to the game into which these systems are built so that users may experience a sense of Presence will be the final challenge, this will mainly come down to asset acquisition.

6.2 Anticipated Results and Success Factors

I anticipate that the proposed AV system will result in a statistically significant improvement to typing performance, and ease of real-world interaction, compared to pure virtuality. Furthermore, I anticipate a statistically insignificant difference in levels of Presence experienced between the AV and virtuality conditions. If this is the case, it will show that minimal blending can be successfully implemented without the use of chroma-key or color segmentation.

7. REFERENCES

[1] Blizzard entertainment. http://us.blizzard.com/en-us/, 2004. Accessed: April-2016.

[2] Konami. https://www.konami.com/en/, 2015. Accessed: April-2016.

[3] Metal gear solid v: The phantom pain - no text chat in mgo3!!!! http://www.gamefaqs.com/boards/718564-metal-gear-solid-v-the-phantom-pain/72609402, 2015. Accessed: April-2016.

[4] Digicapital. http://www.digi-capital.com/news/2015/04/augmentedvirtual-reality-to-hit-150-billion-disrupting-mobile-by-202 #.Vt1irrJ95p9, 2016. Accessed: March-2016.

[5] Htc vive. http://www.htcvive.com/us/, 2016. Accessed: March-2016.

[6] Metal gear solid v: The phantom pain - i miss text chat in mgo. https://steamcommunity.com/app/287700/discussions/0/458606248617248420/, 2016. Accessed: April-2016.

[7] Oculus rift. https://www.oculus.com/en-us/rift/, 2016. Accessed: March-2016.

[8] M. Billinghurst and H. Kato. Collaborative mixed reality. In *Proc. IntâĂŹl Symp. Mixed Reality*, pages 261–284, 1999.

[9] P. Budhiraja, R. Sodhi, B. Jones, K. Karsch, B. Bailey, and D. Forsyth. Where's my drink? enabling peripheral real world interactions while using hmds. *arXiv preprint arXiv:1502.04744*, 2015.

[10] U. G. Foehr. Media multitasking among american youth: Prevalence, predictors and pairings. *Henry J. Kaiser Family Foundation*, 2006.

[11] S. G. Hart and L. E. Staveland. Development of nasa-tlx (task load index): Results of empirical and theoretical research. *Advances in psychology*, 52:139–183, 1988.

[12] S. C. Herring, D. O. Kutz, J. C. Paolillo, and A. Zelenkauskaite. Fast talking, fast shooting: Text chat in an online first-person game. In *System Sciences, 2009. HICSS'09. 42nd Hawaii International Conference on*, pages 1–10. IEEE, 2009.

[13] A. Hutchison. Back to the holodeck: new life for virtual reality? In *Proceedings of the 2nd international conference on Digital interactive media in entertainment and arts*, pages 98–104. ACM, 2007.

[14] C. Jensen, S. D. Farnham, S. M. Drucker, and P. Kollock. The effect of communication modality on cooperation in online environments. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, pages 470–477. ACM, 2000.

[15] M. McGill, D. Boland, R. Murray-Smith, and S. Brewster. A dose of reality: Overcoming usability challenges in vr head-mounted displays. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pages 2143–2152. ACM, 2015.

[16] P. J. Metzger. Adding reality to the virtual. In *Virtual Reality Annual International Symposium, 1993., 1993 IEEE*, pages 7–13. IEEE, 1993.

[17] P. Milgram and F. Kishino. A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, 77(12):1321–1329, 1994.

[18] P. Milgram, H. Takemura, A. Utsumi, and F. Kishino. Augmented reality: A class of displays on the reality-virtuality continuum. In *Photonics for industrial applications*, pages 282–292. International Society for Optics and Photonics, 1995.

[19] J. Peña and J. T. Hancock. An analysis of socioemotional and task communication in online multiplayer video games. *Communication research*, 33(1):92–109, 2006.

[20] T. Shibata. Head mounted display. *Displays*, 23(1):57–64, 2002.

[21] M. Slater and A. Steed. A virtual presence counter. *Presence*, 9(5):413–434, 2000.

[22] M. Slater, M. Usoh, and A. Steed. Depth of presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, 3(2):130–144, 1994.

[23] R. W. Soukoreff and I. S. MacKenzie. Measuring errors in text entry tasks: an application of the levenshtein string distance statistic. In *CHI'01 extended abstracts on Human factors in computing systems*, pages 319–320. ACM, 2001.

[24] J. Steuer. Defining virtual reality: Dimensions determining telepresence. *Journal of communication*, 42(4):73–93, 1992.

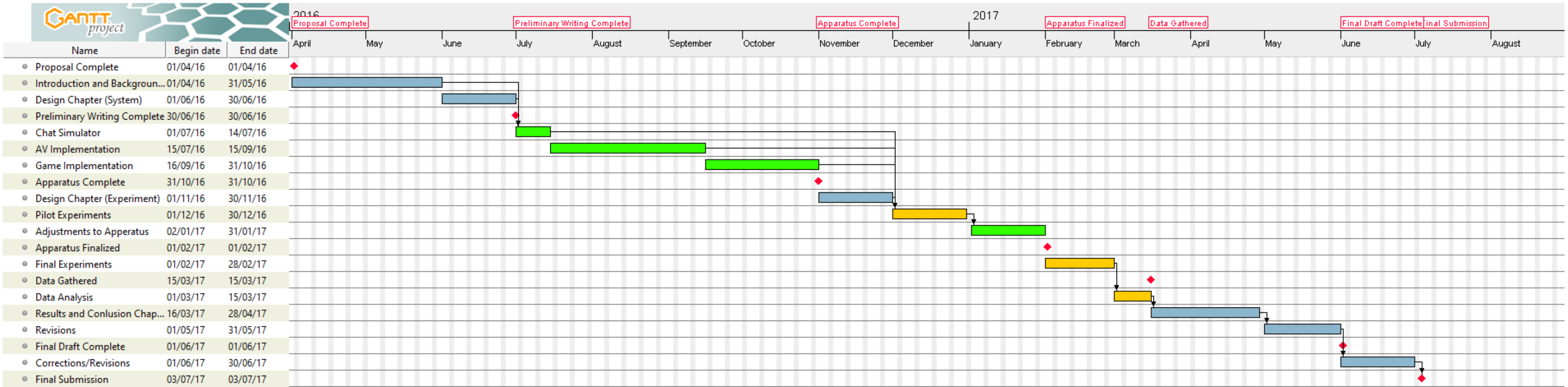
[25] M. Suznjevic, O. Dobrijevic, and M. Matijasevic. Hack, slash, and chat: a study of players' behavior and communication in mmorpgs. In *Proceedings of the 8th Annual Workshop on Network and Systems Support for Games*, page 2. IEEE Press, 2009.

[26] M. Van den Bergh and L. Van Gool. Combining rgb and tof cameras for real-time 3d hand gesture interaction. In *Applications of Computer Vision (WACV), 2011 IEEE Workshop on*, pages 66–72. IEEE, 2011.

[27] D. Weibel and B. Wissmath. Immersion in computer games: The role of spatial presence and flow. *International Journal of Computer Games Technology*, 2011:6, 2011.

[28] B. G. Witmer and M. J. Singer. Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and virtual environments*, 7(3):225–240, 1998.

8. APPENDIX A - PROJECT TIMELINE



Name	Begin date	End date
Proposal Complete	01/04/16	01/04/16
Introduction and Backgroun...	01/04/16	31/05/16
Design Chapter (System)	01/06/16	30/06/16
Preliminary Writing Complete	30/06/16	30/06/16
Chat Simulator	01/07/16	14/07/16
AV Implementation	15/07/16	15/09/16
Game Implementation	16/09/16	31/10/16
Apparatus Complete	31/10/16	31/10/16
Design Chapter (Experiment)	01/11/16	30/11/16
Pilot Experiments	01/12/16	30/12/16
Adjustments to Apperatus	02/01/17	31/01/17
Apparatus Finalized	01/02/17	01/02/17
Final Experiments	01/02/17	28/02/17
Data Gathered	15/03/17	15/03/17
Data Analysis	01/03/17	15/03/17
Results and Conlusion Chap...	16/03/17	28/04/17
Revisions	01/05/17	31/05/17
Final Draft Complete	01/06/17	01/06/17
Corrections/Revisions	01/06/17	30/06/17
Final Submission	03/07/17	03/07/17